Description

This invention is a micromechanical device with a rotating tooth wheel mounted on a substratum. In the future, such tooth wheels and gears may be utilized in the field of medical robotics. The intention would be to adduct miniaturized tools—driven by these devices—through the blood vessels to diseased organs.

In several publications—for example in the US patent specification 47 40 410, or in the publication "Micro Gears and Turbines Etched from Silicon" (Sensors and Actuators, 12 (1987), pp. 341-348)—various movable micromechanical elements are common, such as joints, rotor turbines, and tooth wheels. However, until now there has been no direct drive mechanism to actuate these elements. Common devices may activate these movable elements by use of an externally generated airstream, but this method of actuation is not suited to very slow rotational motion. Furthermore, such devices require that an air supply be conveyed to the device, and a stable connection of the air supply to the micromechanical device is difficult to achieve.

The purpose of this invention is to further study an appropriate micromechanical device that would allow the drive mechanism to act directly on the tooth wheel.

This requirement of the invention will be considered appropriately satisfied when at least two actuator arms—which execute linear movements on a plane parallel to the surface of the substratum—are provided in order to turn the tooth wheel on the surface of the substratum.

Possible variations and alternative uses of the invention will be identified below.

The definition according to Claim 2 offers technical production advantages, since raw materials conventional in the field of microelectronics are used.

According to Claim 3, the device possesses actuator arms that are particularly easy to produce and that function according to the bimaterial effect principle. Through the geometry and configuration of the stratigraphic sequence and the guide mold, a rise in temperature of the guide leads to a linear movement of the non-fixed guide end in the plane of the substratum surface, which is transferred into a rotational movement of the tooth wheel.

According to Claim 4, the layer of the actuator arm proximal to the substratum is to be made of polysilicon, while the layer distal to the substratum is to be made of metal. Metal, for example gold, possesses a considerably higher thermal expansion coefficient than polysilicon. The combination of these two materials produces a highly distinctive bimaterial effect. According to Claim 5, electro-resistors—mounted on or between the layers of the actuator arms—serve as heating elements. Particularly advantageous is a definition in Claim 6, in which one or both of the layers of the actuator arms serve as thermal resistor[s].

As defined in Claim 7, the non-fixed ends of the guide-shaped actuator arms form hooks, which act upon the teeth of the tooth wheel during the linear movement in the plane of the substratum surface. The actuator arms are arranged tangentially around the tooth wheel, and further rotate the wheel by successively acting on a particular disk segment.

According to Claim 8, the tooth wheel possesses six teeth. The teeth and the actuator arms are aligned such that the tooth wheel is rotated 30° during a movement cycle of an actuator arm.

As denoted in Claim 9, all elements of the micromechanical actuator are integrated onto a semiconductor chip. In addition, the power supply for the thermal elements and other electronic circuits can be integrated onto the same chip.

The advantages that the invention has to offer pertain especially to the fact that the rotating tooth wheel, arranged on a substratum surface, can be actuated without an external drive mechanism. To that end, a simple micromechanical motor is provided, equipped with a thermo-mechanical drive mechanism. The thermal energy necessary for the operation may be supplied electrically, which requires only an electrical supply. However, the energy can also be transmitted optically, with the help of a bundled light beam. The concept of this device can offer advantages in microrobotics, medical technology, and the production of micromechanical elements.

The invention shall be described in greater detail in the following delineations.

The following shall be presented:

Fig. 1 Schematic depiction of a micromechanical actuator

a) Plan view
b) Cross-section of the actuator with an unheated actuator arm
c) Cross-section of the actuator with a heated actuator arm

Fig. 2 Schematic depiction of the invented device, whereby rotation of the tooth wheel through a 60° angle is depicted in Fig. 2A – Fig. 2E.

In Fig. 1, a micromechanical actuator is depicted, which serves as a thermomechanical drive mechanism for the tooth wheel.

A cuboid—made of a silicon wafer—serves as the substratum (1). The length and width of the cuboid are several hundred micrometers; the thickness is the same as that of the wafer: 500 µm.

The actuator arm is made up of a T-shaped plate (2) of polysilicon approximately 0.5 µm thick and a metal layer (3) (e.g. gold) of approximately the same thickness. The metal layer partly covers the oblong portion of the T-shaped panel, and the two are securely connected to each other.

In the region of the cross-piece (4), the panel (2) is connected to the surface of the substratum by an approximately 0.5-µm-thick intermediate layer (5). The long piece (6) of the T-shaped panel is non-fixed.

The materials for the panel and the layer were selected so that the excursion of the actuator arm during a rise in temperature would occur in the direction of the substratum surface. It is critical to the functioning of the actuator that a mechanical resistance perpendicular to the substratum surface counteracts this movement. The occurrence of mechanical resistance leads to a bowing of the actuator arm

as well as to a movement of the free end of the actuator arm along the surface in the direction of the fixed end. This movement is indicated by arrows in Fig. 1a and Fig 1c.

During the cooling down of the actuator arm, the movement proceeds along the surface in the opposite direction.

In Fig. 2, a worn device is schematically depicted, in which two actuator arms serve as the drive mechanism for a moveable tooth wheel. The two actuator arms (21, 22) are arranged tangentially to the tooth wheel (23) and comprise an angle of 90°. The non-fixed ends of the actuator arms form hooks (24) and can act upon the tooth wheel. The tooth wheel possesses six pin-shaped teeth (25), whose length allows the actuator arm to act upon a tooth only when it points in the direction of the actuator arm.

Fig. 2A shows the initial position, with both actuator arms outstretched. The tooth indicated by the arrow is pointing to the actuator arm (21).

Once the actuator arm (21) is heated, its non-fixed hook-shaped end (24) moves along the surface of the substratum, carrying the denoted tooth along until the rotation of the tooth wheel has moved the tooth out of the arm's sphere of influence. As depicted in Fig. 2B, another tooth is now pointing to the actuator arm (22) after this rotational movement. Once cooled, the actuator arm (21) assumes its initial position—as shown in Fig. 2C—without moving the tooth wheel.

In the next step (Fig. 2D), the tooth wheel is further rotated by the action of the actuator arm (22). After this arm cools off, it returns to its initial position, with the tooth wheel having achieved a 60° rotation (Fig. 2F). With repetition of the described steps, the tooth wheel is set in rotational motion.

Higher rotational speeds of the wheel and a better tangential feed can be achieved by mounting several actuator arms and teeth.

A possible alternative use that will not be examined in detail here is as a screen for parts or light beams with a selectable aperture. The tooth wheel (23) is furnished with apertures of varying diameters, which are arranged in a circle about the center of the disk. At the same distance from the center of the disk, the substratum has an opening that is brought to convergence with an aperture of desired diameter through rotation of the disk.

Other models may include cutting or milling tools mounted on the tooth wheel so that the device is suited to the processing of materials.

With the appropriate configuration of the invention, the rotational movements of one or several tooth wheels can be transformed back into translational movements. The teeth of the tooth wheel grip the teeth of a serrated rectangular panel and shift this panel on the substratum surface. By this means, a significant increase in the overall reach of an actuator arm can be obtained.

All described configurations are suitable to production via the conventional processes of microstructure technology and microelectronics. Thus both the micromechanical device and the necessary control and evaluation electronics can be integrated onto one chip. During the production process, several identical micromechanical devices can be produced simultaneously on one wafer.

Patent Claims

1. Micromechanical device with a rotating tooth wheel mounted on a substratum. Tooth wheel is rotatable about an axis perpendicular to the surface of the substratum. Characterized by the fact that at least two actuator arms—with regions that execute linear movements in a plane parallel to the substratum surface—are provided for the rotation of the tooth wheel on the surface of the substratum.

2. Micromechanical device outlined in Claim 1, characterized by the fact that the substratum consists of a silicon wafer and the tooth wheel of silicon or a silicon connection.

3. Micromechanical device as outlined in Claim 1 or 2, characterized by the fact that each actuator arm is constructed with two overlapping layers of materials with different coefficients of thermal expansion, that each actuator arm is provided with a heating element, that each actuator arm possesses a primary region—which is bound securely to the surface of the substratum—as well as a secondary, non-fixed region, and is arranged in close proximity and parallel to the substratum surface, and that the substratum surface provides mechanical resistance to the non-fixed region of the actuator arm.

4. Micromechanical device outlined in Claim 3. Characterized by the fact that the layer of the actuator arm proximal to the substratum is to be made of polysilicon, while the layer above that is to be made of metal.

5. Micromechanical device outlined in Claim 3 or 4, characterized by the fact that the heating elements are designed to be electro-resistors, mounted on or between the layers of the actuator arms.

6. Micromechanical device outlined in Claim 3 or 4, characterized by the fact that one or both of the layers of the actuator arms are designed to be thermal resistor[s].

7. Micromechanical device outlined in one of the previous Claims (1-6), characterized by the fact that two actuator arms are arranged tangentially around the rotating tooth wheel on the substratum surface, and that the non-fixed regions of the actuator arms form hooks that act upon the teeth of the tooth wheel.

8. Micromechanical device outlined in Claim 7, characterized by the fact that the tooth wheel possesses six teeth, which are uniformly distributed about the circumference of the disk, and whose length allows the actuator arm to act upon a tooth only when it points in the direction of the actuator arm.

9. Micromechanical device outlined in one of the previous Claims (1-8), characterized by the fact that all elements of the micromechanical device are

integrated onto a semiconductor chip.

Two pages of illustrations here

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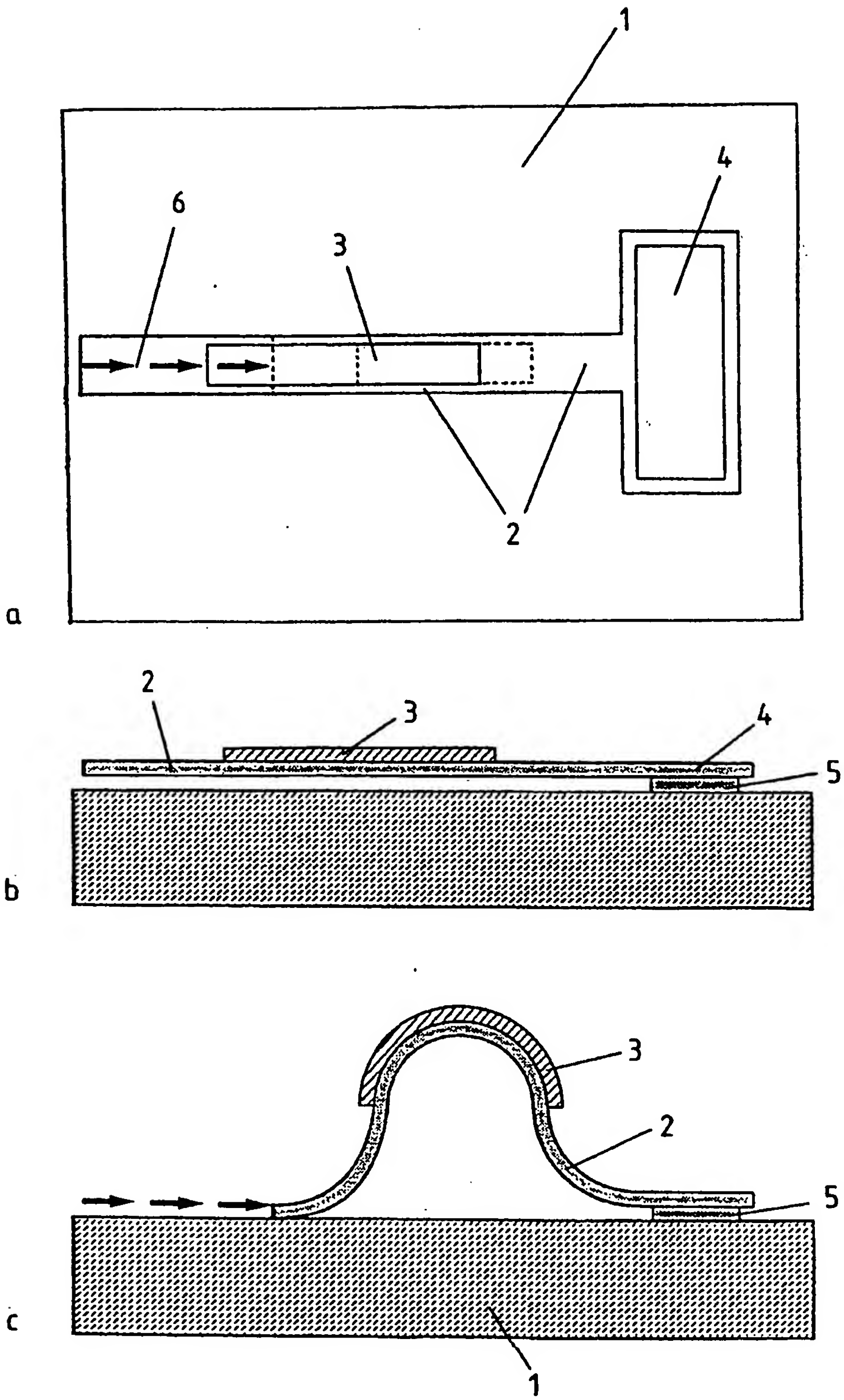

Fig. 1

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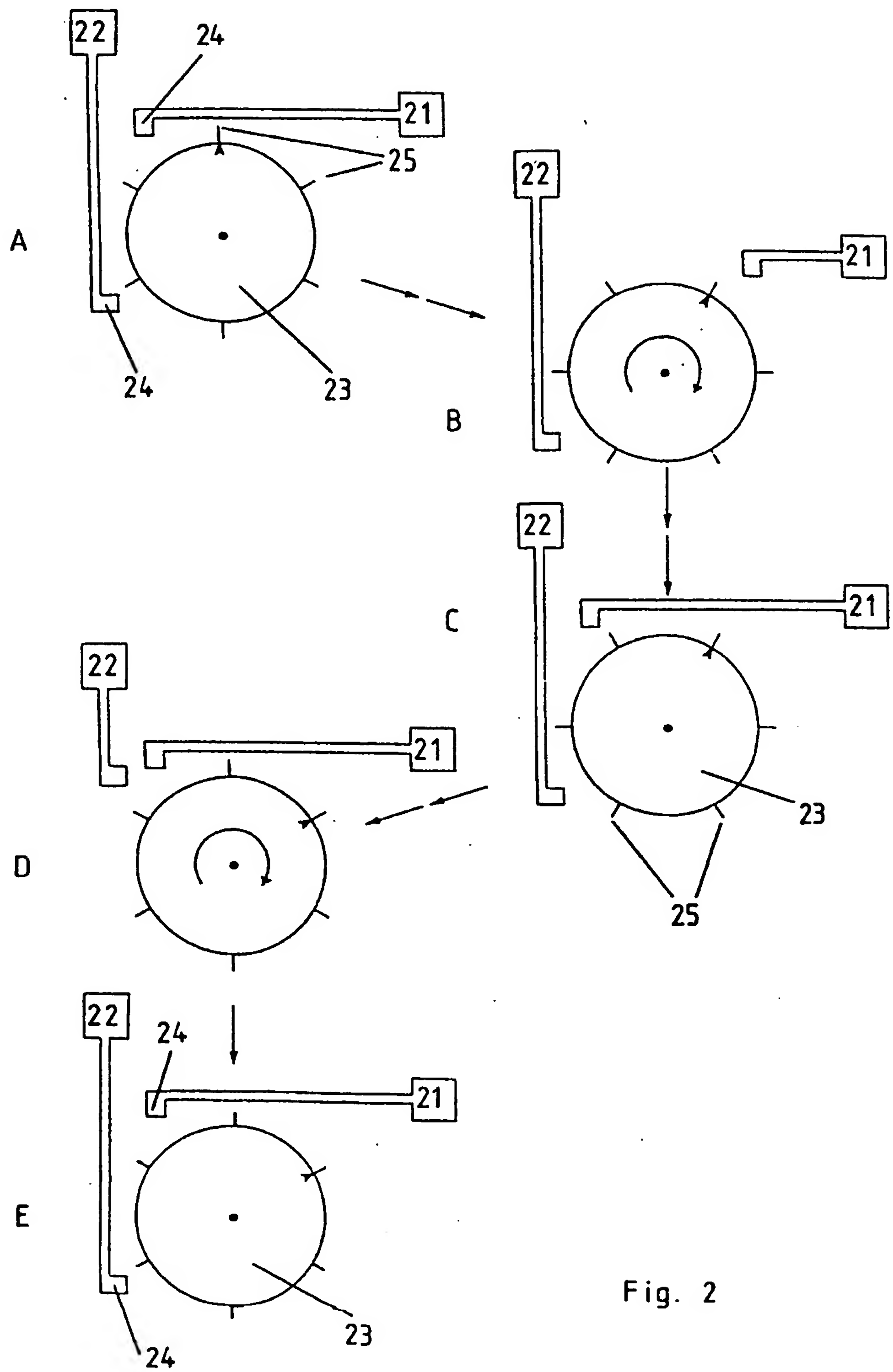

Fig. 2